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The economic and societal impacts of research infrastructures: a literature review in support of evidence-based decision making

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Big science requires big budgets. The ESFRI Roadmap foresees investments of €1,400 million to build 35 multinational research facilities in seven areas of science. Since financing is a national matter, national roadmaps plan for the expenditure of tens or hundreds of millions of Euros per year. The rationale behind such investments is clear: large, state-of-the-art research infrastructures help raise the potential for scientific advances, improve the competitiveness of national science systems, and encourage economic innovation.

There is general consensus among scientists and policy makers that science produces real and significant benefits for economy and society. Citizens tend to agree. According to several Eurobarometer surveys (2005; 2007), the average European citizen is highly interested in the results of scientific research and believes that science has a positive impact on society. Citizens are, however, reluctant to support higher levels of expenditure.

The opportunity costs of investments in science seem high. In a context of scarce public resources, the financial needs of public science compete with alternative expenditure options that seem to produce more predictable and visible benefits in the shorter run, such as improvements in education, public health care, and transport infrastructure. The benefits of scientific research are more uncertain, take longer to materialise, and are more difficult to substantiate, especially for fundamental research.

Opportunity costs are higher during an economic crisis. The combination of a strain on public finances and the uncertain long-term returns on investments in science can tempt politicians to postpone investments in the knowledge infrastructure and reallocate available funds. Budget cuts and short-term urgent needs may drown out longer-term structural needs. Such decisions do, however, affect future scientific and innovative capacity.

Any decision to invest in the knowledge infrastructure should therefore be based on sound evidence and a careful comparison of available options. The necessary evidence should support decisions on three levels:

- The decision whether or not to invest in the knowledge infrastructure is a political one and involves careful consideration of costs and benefits as well as potential risks; the pressures of international competition in science, innovation, and growth; and the opportunities to mobilise science to solve societal problems.
- Within scientific disciplines competition is global, resulting in demand for state-of-the-art technical facilities and infrastructures. Within countries, scientists compete across disciplinary boundaries for investment funding from a limited number of sources. Since all scientific disciplines are looking to develop large-scale infrastructures, government has

to find a way to compare apples and oranges in evaluating funding proposals as well as to evaluate the non-scientific benefits that are of general interest.

- In the design stage, decisions involve strategic considerations on the specific shape of an infrastructure. Should research facilities, laboratories, or research centres be large or small, developed in collaboration or alone, geographically concentrated or dispersed, and 'in vivo' or 'in silico'?

Method

There is a lack of direct scientific evidence on the nature and extent of the impacts of large-scale research infrastructures on science, economy, and society and on the mechanisms that generate such effects. What we do know is biased towards the demands of economic innovation. In this paper we review the extant literature to determine, from the perspective of science, the net benefits to society of organising research on a large scale, in collaboration or on a specific geographic location.

The central question is whether or not and, if so, through which mechanisms research infrastructures produce economic and societal impacts. We have examined different relevant strands of research, viz.:

- Social networks and knowledge spillovers around big science centres, notably CERN.
- Studies relating to specific large-scale research facilities of predominantly national importance.
- Multi-institutional scientific collaboration involving partners from science, business and society, and focusing on their motivations for collaboration and the effects of a confluence of interests in a facility or research centre.
- Knowledge spillovers in relation to large-scale facilities and mission-oriented laboratories, including studies of human capital mobility, social networks in science, and university spin-offs.
- Science parks and other aspects of geographic concentration in scientific knowledge production and their impacts on economy and society.
- The rise of virtual and distributed facilities as a substitute for large single-sited and mobile facilities.

The results of the literature review will be used to support evidence-based decision making with regard to some of the main criteria for national investments in scientific capital goods. We will qualify three key assumptions that are used to justify investment decisions, evaluate investment proposals ex ante, and test research infrastructure performance ex post. Research infrastructures:

- attract talented researchers from abroad and help retain domestic talent for science;
- directly and indirectly promote innovation in the public and private sectors;
- are a focal point for collaboration among a multitude of actors and produce synergy among the producers of knowledge.

Results

One of our initial findings is that economic and social impacts cannot be considered entirely external. In many cases these effects are endogenous to the science system. An application of Larédo and Mustar's model of laboratory activity profiles (*Scientometrics*, 47:3, 2000) to an inventory of large-scale research facilities in the Netherlands reveals that more than half of the facilities have non-scientific primary objectives. While this lends further support to the integration of science, economy and society, it also suggests that economic and societal impacts can be inherent to the design of research facilities and that there are considerable opportunities for joint investments by public and private actors. In addition, the literature provides evidence to suggest that the effects generated by research infrastructures are conditional upon the nature and design of the infrastructure as well as the actors that participate, and that (informal) social networks between actors are a major mechanism of knowledge spillovers.

Our review will draw meaningful conclusions about the role of research infrastructures in innovation, human capital mobility, regional economic development, and the dynamics of the science system.

Keywords: big science; research infrastructures; knowledge spillovers; public investments in science and innovation

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